Design Automation Algorithm for Soft Robots

Completed Technology Project (2013 - 2017)

Project Introduction

The majority of design to manufacturing today is still an ad hoc and empirical process. There is a direct need for a single, automated design and fabrication process. Furthermore, new fabrication techniques at the micro and macro scales provide nearly unlimited design and product potential, for which there is no design precedent. Empirical design will not transfer to the projects that are capable of being produced with these techniques (or example, mobile soft robots), because human intuition will fail when trying to predict the performance of non-linear interactions between novel materials and forms at multiple scales. I propose that Evolutionary Algorithms (EAs) are used to iteratively and interactively produce designs. EAs mimic the traits of biological evolution and apply them to artificial design of novel and unintuitive solutions. They have been shown to create complex and interesting forms with interactive feedback from a human user, and also have been shown to create high performing solutions when left to optimize product design towards one or more objective feature. Examples of EA performance include a part deployed on the NASA ST5 spacecraft which outperformed all of the alternative human designed solutions or specialized crumple zones in industry leading automobiles. The universal design tool I propose will take advantage of computational precision and speed to create an array of high performing designs, then take advantage of a user's human intuition to judge and select designs according to intuitive properties that the computer cannot compute on its own (e.g. designs that are novel, interesting, attractive, or promising). The fact that different pressures are shaping the design from different systems (the user's preferences and the computer's performance metric) will overcome many of the problems with local optima and lack of diversity that EAs have faced in the past. Additionally, recent work has shown that the use of drivers such as interestingness or novelty can be more effective drivers of EAs than a direct performance metric. The iterative design process of an EA means that there is always a functionally viable, fully described, design that is being optimized. Thus at any point in time, the best current design can be sent to a 3D printer for immediate fabrication. This design tool would contain properties such as: Immediate and individualized fabrication potential of current designs; Lack of need for domain specific knowledge or for full intuition of the (usually non-linear) constraints and processes occurring (and being optimized) at multiple scales; And the sole requirements of a high level performance metric and general human intuition. These make this system ideal for design optimization at any scale - whether it be as large and rigorous as a NASA spacecraft or as quick and simple as a cleaning robot at home or a load bearing frame at an industrial job site. Additionally, since the design process is iterative and based off of rigorous simulation and validation from a performance model, all products that come out of this system will have a digital twin - a simulated version upon which additional tests, circumstances, or project mirroring can take place.

Design Automation Algorithm for Soft Robots

Table of Contents

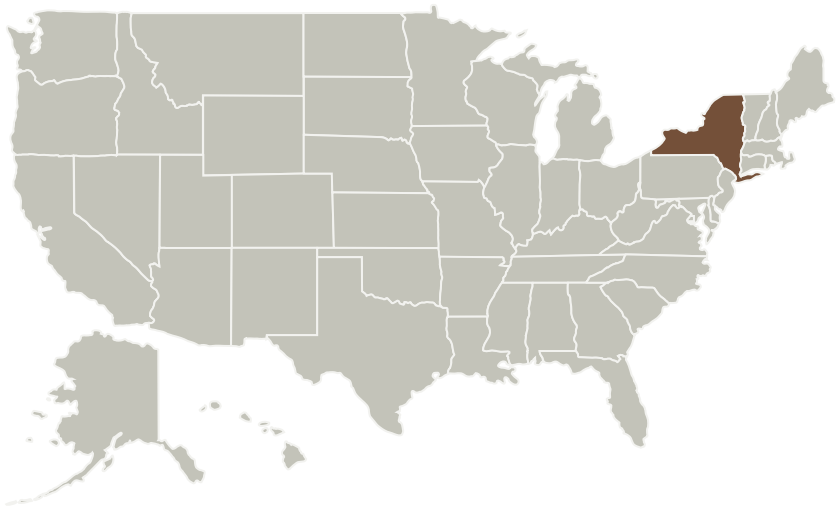
Design Automation Algorithm for Soft Robots

Completed Technology Project (2013 - 2017)

Anticipated Benefits

This design tool would contain properties such as: Immediate and individualized fabrication potential of current designs; Lack of need for domain specific knowledge or for full intuition of the (usually non-linear) constraints and processes occurring (and being optimized) at multiple scales; And the sole requirements of a high level performance metric and general human intuition. These make this system ideal for design optimization at any scale - whether it be as large and rigorous as a NASA spacecraft or as quick and simple as a cleaning robot at home or a load bearing frame at an industrial job site. Additionally, since the design process is iterative and based off of rigorous simulation and validation from a performance model, all products that come out of this system will have a digital twin - a simulated version upon which additional tests, circumstances, or project mirroring can take place.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Cornell University	Lead Organization	Academia	Ithaca, New York

Primary U.S. Work Locations
New York

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Cornell University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Steven Strogatz

Co-Investigator:

Nicholas A Cheney

Design Automation Algorithm for Soft Robots

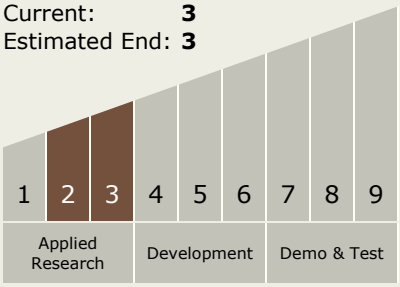
Completed Technology Project (2013 - 2017)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  - TX11.5 Mission Architecture, Systems Analysis and Concept Development
    - TX11.5.2 Tools and Methodologies for Performing Systems Analysis

Target Destination

Foundational Knowledge